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Recovery and use of olive stones: Commodity, environmental and economic assessment

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ABSTRACT

At the present time biomass (together with sunlight) is the most equally distributed and easily exploited energy resource. Of the various types of biomass, that deriving from agricultural by-products is proving to be of growing interest thanks to the ease with which it can be accessed and processed, its energy concentration and the "ethical" acceptability of this fuel (that does not derive from specifically grown crops but from the by-products of the agricultural industries). In addition, a number of potential environmental problems may be resolved.

In particular, during the production of olive oil it is possible to recover olive pits as a by-product for energy production for use as fuel in domestic boilers or in large industrial plants for cogeneration.

This study evaluates the commodity, environmental and economic aspects linked to different techniques for the pit recovery from olive pulp and olive pomace. The economic and environmental viability of these new "best practices" has been demonstrated both at the level of production (increased income for olive extraction plants) and at the level of environmental sustainability (use of renewable fuels).

Contents

1. Introduction

Biomass has an important place among the energy resources that are considered renewable. The presence of biomass throughout the territory and the absence of specific constraints on access to it, mean that its use needs to be seriously considered within a framework of reduction of dependence of fossil fuels. The possible energy uses of biomass as a substitute for fossil fuels include the production of heat for heating purposes, the production of electrical energy and cogeneration [1–14]. The European Union has introduced a number of measures to encourage the use of renewable energy sources, including the EC Decree 2003/30 and the Decree proposal of 23rd January 2008 which will come into force in 2010. Such measures offer an important opportunity to businesses in the food and agricultural industries that may thus re-utilise by-products, as well as providing a sound agronomic and environmental alternative to the disposal of the latter [15]. The biofuels obtained can then be marketed and offer further income for those working in the sector.

A major opportunity within the olive oil production industry is the exploitation of certain by-products obtained during the processing of olives for oil, such as pomace and olive pits, which can be used as biofuels [16–21].

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Table 1
Characteristics of biomass fuels and conditions of use [23].

Characteristic	Unit	Min/max values
Ash	% (m/m)	≤4
Moisture	% (m/m)	≤15
N-hexane	mg/kg	≤30
Organic solvents	Absent	–
Lower heating value	MJ/kg	≥15.7

The most important Italian legislation on the subject is the previous Prime Ministerial Decree of 8th March 2002 [22], in which virgin pomace was considered as a vegetable fuel that may be freely used (annex III comma 1 letter e), while exhausted pomace, which has undergone a chemical process, was categorized as non-dangerous waste and was therefore subject to constraints. Subsequently, with the passing of the legislative Decree no 152 of 3rd April 2006 [23] and the Prime Ministerial Decree of 8th October 2004 [24], the earlier Prime Ministerial Decree of 8th March 2002 was modified and exhausted pomace was categorized as a fuel used in the plants regulated under sections I and II of the fifth part of the legislative Decree 152/2006, in particular in annex X, part II, section 4, in which the characteristics of biomass fuels and their respective uses (Table 1) are detailed. Therefore, in order to be considered as a potential "biomass" fuel the exhausted de-oiled pomace must possess the characteristics reported in Table 1 and must bear on the label the name of the production plant, the year of production and certification of respect for the characteristics listed.

With the passing of the Prime Ministerial Decree of 8th October 2004 (annex III) pits from olive pomace were included in the category of biomass fuels as vegetable matter produced exclusively from the mechanical processing of agricultural products.

The data published by ISTAT (the Italian Central Statistics Office) relating to olive production destined for the extraction of oil were used to calculate the quantity of biomass that may theoretically be obtained from these crops (at a national level).

In Table 2, and in the third column in particular, an estimate is made of the quantity of virgin pomace produced with the extraction systems currently in use, i.e. the traditional systems of discontinuous extraction (20%), two-phase continuous extraction (15%), and three-phase continuous extraction (65%). The fourth column reports an estimated pit production, calculating a variable quantity ranging from 8 to 15% of the weight of the olives processed, depending on the separation technology used. These values may contribute to an increase in the biomass available for energy use, with a possible saving of between 100,000 and 180,000 tonnes of heating oil (our calculation based on ISTAT data) [25].

Table 2
Quantity of olives for oil and estimates of virgin pomace and pits produced in the period from 1999 to 2007 in Italy (in tonnes) [25].

Year	Olive production for oil	Estimate of virgin pomace [a]	Estimated pit production[a]
1999	3,689,622	1,845,000	295,000–553,000
2000	2,740,612	1,370,000	219,000–411,000
2001	3,302,287	1,651,000	264,000–495,000
2002	3,174,012	1,587,000	254,000–476,000
2003	3,484,043	1,742,000	279,000–523,000
2004	4,470,832	2,235,000	358,000–671,000
2005	3,713,664	1,857,000	297,000–557,000
2006	3,354,155	1,677,000	269,000–503,000
2007	3,194,067	1,597,000	256,000–479,000
Average 1999–2007	3,458,144	1,729,000	277,000–519,000

[a] Our estimates based on ISTAT data [25].

2. By-products of the olive oil industrial process

The transformation of olives into oil produces two types of by-products:

- vegetation waters, which can be either waste for disposal or can be used for irrigation and fertilisation and
- pomace is a by-product made up of a cellulosic residue containing in part fibre from the fruit and partly fragments of olive pits [26].

In Italy the pomace is generally used to extract crude pomace or as a soil amendment. In Spain, where nearly all the systems use centrifuges for the extraction of the oil, the end use is the production of energy and heat in cogeneration plants [27].

The commodity characteristics and the quantities of virgin pomace produced depend on the techniques used for oil extraction (Table 3). However, when choosing among the various production technologies available, these characteristics are secondary to considerations affecting the quality of the oil. This by-product has a moisture content that can range from between 22 and 35% with the pressing method and up to 65–75% in plants with two-phase extraction. The remaining content is residual oil (less than 5%) and pulp (from between 10% in continuous systems up to 30% in pressing plants) and olive pits. The pit content varies from 30% in pressing plants to 12% in the two-phase continuous systems [28].

Until recently virgin pomace was a supplementary source of revenue, at least in Italy, for olive mills using the pressing system as pomace processors paid an interesting price for this by-product (roughly 3–4 euro/100 kg). This revenue allowed mill-operators to cover the costs of waste disposal of the olive mats and major maintenance on the machines, as well as avoiding extra expense for disposal of the pomace. The introduction of the three-phase centrifuge decanters brought about changes to the commodity characteristics of the virgin pomace obtained and led to a consequent decrease in its value due to the lower oil content and/or the high percentage of water present. Thus the pomace processors that used this by-product as their raw material necessarily paid a considerably lower price (on average 50% less).

3. Technological and commodity aspects related to the separation of the pit from the pomace

A number of different technologies have been introduced to increase the value of pomace, with a view to exploiting the by-products from the olive oil production process and increasing mill revenue while reducing environmental impact. These technologies make it possible to separate the woody part of the drupe, the pit, in the following ways:

Table 3
Quantity and characteristics of virgin pomace obtained with different extraction systems for olive oil [28].

Measurements	Pressing	3-phase decanter	3-phase decanter [a]	2-phase decanter
Quantity (kg/t olives)	250–350	450–550	550–650	800–850
Moisture (%)	22–35	45–55	55–62	65–75
Oil (% on fresh pomace)	6–8	3.5–4.5	3.5–4.5	3–4
Pulp (%)	20–35	15–25	12–20	10–15
Stones (%)	30–45	20–28	15–20	12–18
Ash (%)	3–4	2–4	3–4	3–4
Nitrogen (mg/100 g)	250–350	200–300	200–300	250–350
Phosphorous (mg/100 g)	40–60	30–40	35–45	40–50
Potassium (mg/100 g)	150–200	100–150	100–180	150–250
Total phenols (mg/100 g)	200–300	200–300	250–350	400–600

[a] 3-phase decanter centrifuge with re-cycling of vegetation waters.

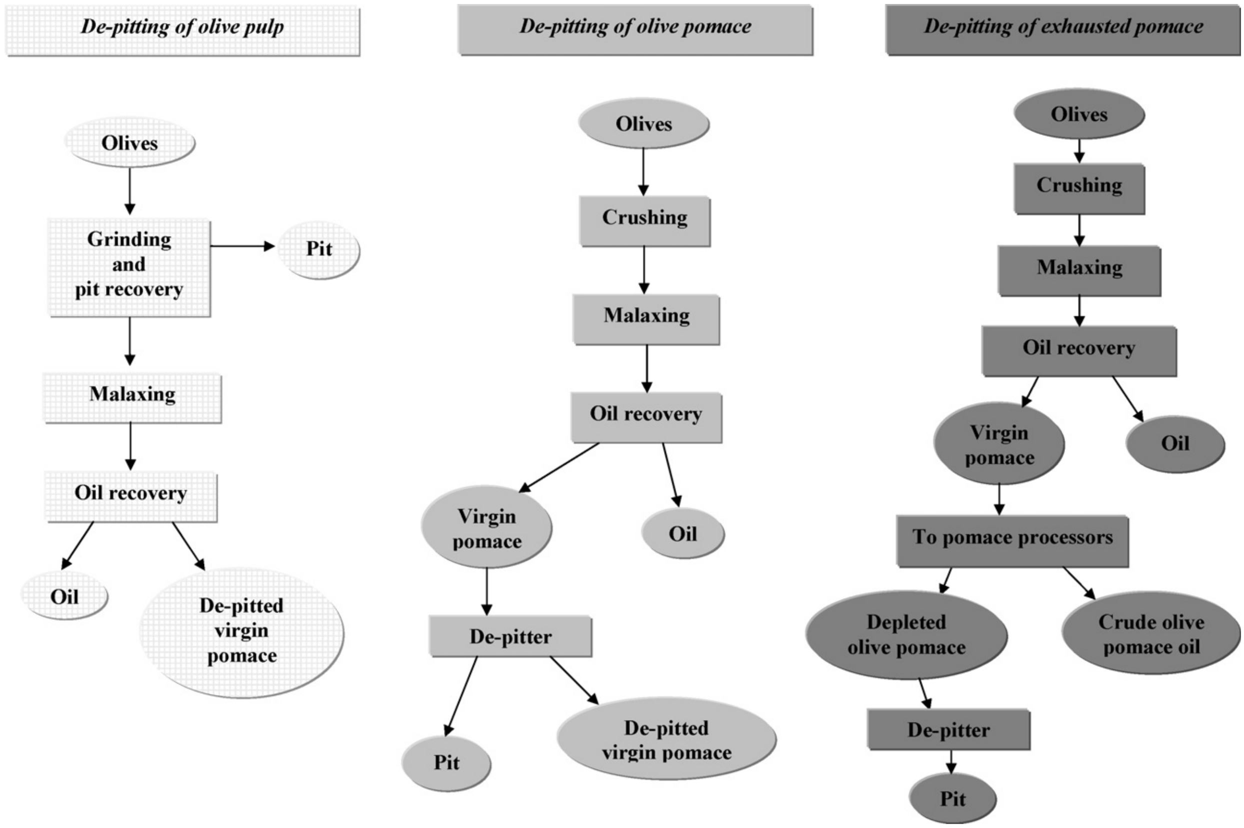

Fig. 1. Pit recovery systems.

- during the extraction of the olive oil through the de-pitting of the olives, or by recovering the pit from the olive paste;
- by recovering the pits from the virgin or exhausted pomace (Fig. 1).

Furthermore, it is possible to separate the pit whole during the processing of pitted table olives.

The pit deriving from olive paste or from the pomace of virgin olive oil is generally obtained at the mills themselves with the use of specific machines that carry out mechanical operations such as centrifuging. This fuel may be used in the oil processing plant to heat the water used for grinding the olives or marketed as an alternative fuel to wood pellets [27,29,30]. The pits may also be used to produce synthesis gas or cellulose, hemicellulose sugar, etc. [31].

When the pits are obtained from olive paste they are separated in a machine that performs both the crushing, using opposing rollers, and the subsequent separation from the paste and offers a yield of 15% of the olives processed. This process, however, affects the chemical, physical and sensory characteristics of the oil which is extracted from de-pitted paste. These characteristics, which have been examined in numerous scientific papers, do not form part of this study.

On the other hand, when the pits are obtained from virgin pomace, they are separated by centrifugation without the addition of solvent or chemical substances. The type of pomace processed (coming from two-phase or three-phase extraction plants), will determine both the quantity of pits that may be extracted and the fuel moisture. Between 12 and 20 kg of pits can be recovered from 100 kg of virgin pomace (roughly 8% of the quantity of olives processed) with a moisture content of about 20%. Normally, the moisture is then reduced to values of between 6 and 12% using natural or artificial drying methods. After this separation the remaining de-pitted pomace may be used for different purposes. The pits may be recovered from the pomace with or without the addition of water. When water is added to dilute the mass it increases the moisture in the residual pulp (roughly 70%) and thus leads to a further lowering of the price of the material, meaning it is no longer suitable for the pomace processing plants.

The de-pitted pomace, following further drying, may however have other uses, such as an addition to animal feeds [32–35], in agronomy for open field fertilisation, for compost production, to produce a growing substrate for plant nurseries or as a source for the extraction of compounds used for cosmetics or drugs [36,37].

The pits from exhausted de-oiled pomace coming from pomace processing plants and obtained by depowdering the exhausted pomace, which is treated with chemical solvents, is a suitable fuel for large combustion plants that have devices that permit a reduction in fumes and the removal of ash. The use of such a fuel in domestic boilers, however, gives rise to a number of problems related to its lighting, to its unpleasant smell and to the dirt that collects in the heat exchangers and in the flue. The use of pomace as a fuel poses similar problems, but the cost is up to 50% lower and it is more readily available.

Like biomass, the pits have many advantages as they are available throughout the winter, they do not contain fragments of leaves, pulp, skins and powder such as those found in the pomace and they produce less fumes and ash. As for other fuels, the heating value depends on the moisture content and ranges from approximately 17 MJ/kg (moisture 10%) to roughly 20 MJ/kg (moisture 6%) compared to roughly 19 MJ/kg in pomace and wood pellets [38–40].

The last line of Table 3 reports the higher heating value of the pit; this does not differ greatly from that of the alternative fuels and is higher that of the pellet commonly used for household heating, however the ash content is higher though it does not go beyond 2.3%.

Table 4 reports the commodity characteristics of the extracted pits and others alternative fuels [8].

Table 4
Characteristics of some alternative fuels [8].

Analysis	Residues			
	Forest pellet	Tomato pellet	Olive pit	Cardoon Pellet
Ultimate analysis (%)				
C	46.5	52.3	46.5	39.1
H	6.8	7.6	6.4	6.0
N	1.9	3.4	0.4	2.0
S	0	0.074	0	0.14
Cl	0.03	0.12	0.34	1.21
Proximate analysis (%)				
Fixed carbon	13.8	9.4	16.2	14.9
Volatile matter	76.4	80.1	72.7	62.9
Ashes	1.0	3.5	2.3	11.3
Moisture	8.8	7.0	8.8	10.9
HHV (MJ/kg)	18.4	22.7	19.4	14.8

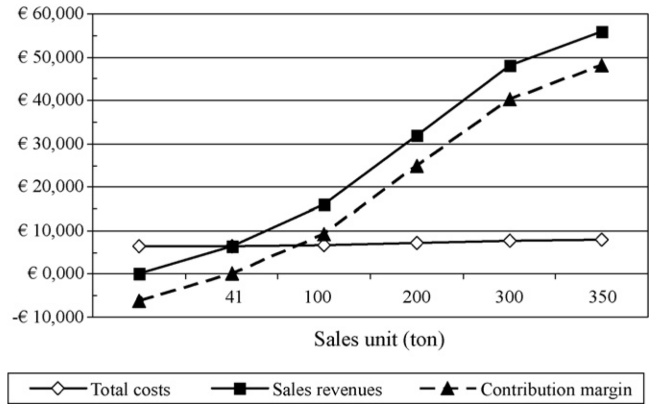

Fig. 2. Calculation of the break even point for the system of pit extraction from olive paste (case study 1).

4. Economic aspects

This study has examined two pit recovery processes:

- the first uses olive paste directly, before the oil is extracted (case study 1) and
- the second, uses virgin pomace (case study 2).

In the first type of plant, once the olives have been sorted and washed they are crushed using two opposing rollers and the olive paste thus obtained is then centrifuged in the same machine, in order to remove the pit. On average this method produces 150 kg of pits from 1 ton of olives, equal to about 75% of that contained in the paste. Production capacity is approximately 0.7 ton/h of pit with an electricity consumption of roughly 0.2 kWh/ton. The de-pitted pomace has a moisture content of around 50%.

The second type of plant, on the other hand, separates the pit from the virgin pomace, without the addition of water, dividing the two main components: the pulp and the pits. The pomace used in case study 2 comes from three-phase continuous plants. Production capacity is roughly 1 ton/h of pit with an electricity consumption of roughly 0.1 kWh/ton. The de-pitted pomace has a moisture content of between 40 and 45%.

In order to assess the economic convenience of these two plants the costs and revenue linked to their purchase and running were analysed and processed. The data were collected in a series of interviews carried out on a representative sample of olive mills in Abruzzo and Apulia regions where these plants are present. The subsequent processing of the data collected enabled us to form economic hypotheses on the purchase and running of the two types of machinery. Certain assumptions were made at the basis of the economic calculations in order to simplify the economic and financial analysis. The forecast hypothesized that the activity of producing biomass for energy purposes was separate (from an economic point of view) to that of oil production. A review of all the items in the economic accounting shows that:

- the cost of the pomace used was hypothesised as being zero given that the olive mills can use it without incurring any costs;
- the selling price of the olive pit produced was considered to be 150 euro/ton ex-plant, even though in the previous six months the price showed increases of up to 20–30 euro/ton;
- after separation from the pits the fibre can be disposed of (as waste or used as soil amendment or for compost production) at no extra cost. The de-pitted pomace deriving from case study 1 contains a residual quantity of pit and the pomace processing plants pay roughly 10 euro/ton for this material; that coming from case study 2 can also be sent to the pomace processing plants which do not, however, pay for this material (transport costs are also excluded). Consequently, the accounting considered the absence of any profit derived from the sale of the pomace as well as the costs of the transport of the pomace to the pomace processing plants;
- the purchase cost of the machinery was 30,000 euro for case study 1 and 15,000 euro for case study 2, and thus the period of amortization for the machinery was calculated at 5 years, because even though its actual working life is much longer (over 10 years) it was hypothesized that the economic utility of the machinery is limited to the former period;
- machinery maintenance, in accordance with the indications of the manufacturers, was calculated in case study 1 at a cost of 500 euro every 500 working hours; in case study 2 maintenance costs were calculated at 1000 euro every 500 working hours, including both labour costs of a technician and spare parts;
- electrical energy costs were calculated on the basis of the rates of the Italian Electricity and Gas Authority (AEEG), and considering a peak use of 20 kW, which would include energy absorbed by other auxiliary plants. On the basis of these rates a cost of 0.104 euro/kWh was calculated for the F1 hourly rate [41] and
- the labour costs were calculated on the employment of a unit of staff for an estimated time of 1 h/day, with the tasks of checking the correct functioning of the plant and the storing of the output from the production cycle (pits, pulp). Hourly costs were considered to be 10 euro/h and the totals were calculated bearing in mind the differing production capacity of the plants considered.

Figs. 2 and 3 show the values of the total costs and total income, and the minimum quantity of pits necessary to ensure that revenue was greater than the costs (break even point) was thus calculated.

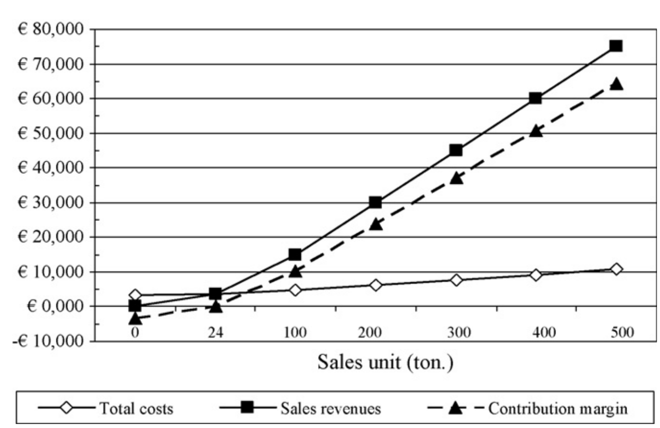

Fig. 3. Calculation of the break even point for the system of pit extraction from the pomace (case study 2).

Table 5
Quantity of olives to be processed in relation to the quantity of pits produced.

		Quantity of pits produced (in tonnes)				
		100	200	300	350	500
Quantity of olives to be processed	Case study 1	666	1332	1998	2331	
	Case study 2	1110	2220	3330		5550

As can be seen from Fig. 2 the break even point is at 41 tonnes of pit obtained from roughly 270 tonnes of olives processed, while in Fig. 3 the break even point drops to roughly 24 tonnes of pit recovered from approx. 271 tonnes of olives processed. This difference can be explained by the price of the machinery used for separating the pits from the olive paste (case study 1) which is considerably higher than that of the machinery that carries out the separation on virgin pomace (case study 2).

It should also be noted that the contribution margin obtained in case study 2 is higher than that of case study 1, for the same quantity of pit obtained.

However, it should be considered that in case study 2, it is necessary to process a greater quantity of olives to obtain the same quantity of pits as that in case study 1. This means that some of the smaller olive mills with a reduced working capacity are necessarily excluded. Table 5 reports the quantity of olives that must be processed in relation to the quantity of pit produced. The last two columns show the maximum quantity of olives that can be processed by the two systems analysed, when an operating time of 500 h/year is considered.

The machine used for removing the pit from the olive paste (case study 1) yields a higher quantity of pit (150 kg/ton of processed olives) compared to that in case study 2 (90 kg/ton of processed olives) using pomace obtained from three-phase continuous systems.

It should also be considered that the pomace de-pitter requires more maintenance and has a greater risk of break-downs due to the more abrasive action of the pomace.

5. Conclusions

The use of olive pit as a biofuel offers an alternative in the agricultural industry to the use of fossil fuels and could contribute to a reduction in CO_2 emissions. Legislation has been passed offering incentives for the use of biofuels, making their use even more interesting. On the one hand a number of different technologies have appeared on the market for recovering pits from pulp or virgin or exhausted pomace, thus increasing the supply of this biofuel, while on the other hand boilers for its use have been developed.

This study analysed two different technologies for pit recovery and both were shown to be economically viable.

The de-pitter considered in case study 1, which carries out first the grinding and then recovers the pit, produces oil from de-pitted olive paste with particular sensory characteristics.

The de-pitter in case study 2, that recovers pits from virgin pomace obtained after the oil has been removed from the olive paste, has lower investment costs but requires large quantities of olives for processing and is thus suitable only for larger olive-processing plants.

Studying the choice between these two technologies within the territorial context, it emerges that while in some regions both technologies may be used, in other regions where the olive mills are smaller, the olive pulp de-pitter is the necessary choice.

In conclusion, it can be stated that pit recovery is seen to be economically viable as it offers supplementary income for the olive mills, which can expand their activities, and provides an interesting biofuel for sale within the area of agricultural energy, together with other by-products from the agricultural industry. The environmental aspect is no less important, above all when using a "short production process" approach which offers an alternative to the use of biomass coming from far away (such as palm-oil) the use of which necessarily involves significant environmental effects connected to transport. It is thus to be hoped that these technologies will become widespread in the olive oil production process.

Contribution of authors

This paper has been thought, discussed and written by the three authors and it is the result of their common commitment.

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